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of

David F. Hepner

and

Andrew D. Walls

For

**COMPUTER-COMPONENT POWER-CONSUMPTION
MONITORING AND CONTROL**

COMPUTER-COMPONENT POWER-CONSUMPTION MONITORING AND CONTROL

BACKGROUND OF THE INVENTION

1. The Field of the Invention

This invention relates to digital computers, and more particularly, to unique apparatus and methods for conserving and managing power allocated to expansion cards and other devices within a computer system.

2. The Relevant Art

In an effort to increase the functionality, flexibility, and utility of today's personal computers, workstations, servers, and the like, expansion buses such as the PCI (Peripheral Component Interconnect) bus have been provided to enable a user to mix and match desired add-on components in a computer system. Expansion buses typically interface with the main bus or local bus connected to a CPU through a bridge or other interface device. Thus, an expansion bus may operate at a different clock speed and may use different data transfer protocols than are used by a CPU and associated components connected to a local bus.

As add-on or expansion components continue to have improved performance, various existing expansion bus technologies may be reaching their limits in terms of data rates, power consumption, expandability, and the like. Moreover, as performance of these components continues to increase, the amount of power these components consume becomes an important issue to proper operation of an expansion bus. Most buses are designed to allocate pre-determined amounts of power to components connected thereto. For example, the PCI bus specification allocates 25 watts to each connected device. Nevertheless, certain components may exceed this rated allotment at times, thereby overloading the bus and associated power supply.

Power supplies are often expensive compared to other components in a computer

1 system. The cost of a power supply may be directly related to its rated wattage. Thus,
2 providing a power supply that is sufficient for a system, with little excess capacity, may
3 contribute to keeping the cost of computers relatively low. Moreover, apparatus and methods
4 used to decrease power consumed by components in a computer may enable a computer to
5 have a lower rated power supply.

6 Moreover, various expansion cards may use excessive amounts of power, even when
7 used very little. That is, due to leakage currents, high clock speeds, and the like, even when
8 an expansion card is doing very little actual work or processing, power may be unnecessarily
9 wasted. The use of multiple expansion cards may compound this problem, each consuming
10 more power than is necessary. Situations such as these may easily overload rated power
11 supplied by a bus, such as a PCI bus. Moreover, as various computing components continue
12 to decrease in size while they increase in performance, the need for more power may make
13 the devices larger than is necessary due to battery size.

14 Thus, apparatus and methods are needed to regulate, allocate, and control power
15 provided to devices, such as expansion and add-on cards connected within a computer
16 system. Apparatus and methods are further needed to adjust device parameters such as clock
17 speed, logic wait states, and the like within an expansion or other device to decrease the
18 power required by such devices.

SUMMARY OF THE INVENTION

In view of the foregoing, the present invention provides apparatus and methods for regulating, allocating, and controlling power provided to devices, such as expansion and add-on cards connected in a computer system. In addition, apparatus and methods capable of adjusting device parameters such as clock speed, logic wait states, and other parameters of expansion or other devices to decrease power used in a computer system are provided.

In accordance with the invention as embodied and broadly described herein, an apparatus for regulating power allocated to components within a computer system is disclosed. In one embodiment of the present invention, the apparatus includes a sensor configured to sense power drawn by a first device within a computer system. A power-monitoring module is provided to monitor the power drawn and functional demand required of the first device. A system control module, operably coupled to the power-monitoring module, is provided to regulate power allocated to the first device by optimizing use of resources associated with the device in accordance with the functional demand of the first device. A second device may operate with power thresholds determined in part by parameters of the first device. For instance, heavy current use of demand on the first device may be sensed and the power usage of the first device reduced.

In selected embodiments, a second sensor is provided to sense power drawn by a second device within the computer system. The system control module is further configured to regulate power allocated to the second device by optimizing use of resources associated with the device in accordance with the functional demand of the second device. In certain embodiments, device resources include a processor, a memory device, a device clock, or other components. The sensor may sense current drawn or voltage characteristics of the power drawn.

In selected embodiments, the first and second devices are PCI expansion cards, ISA expansion cards, onboard devices on a motherboard, or a combination thereof. In fact, the first and second devices may be expansion or add-on cards or devices connected to any type

1 of high-speed bus or point-to-point switching system including multiple devices.

2 In selected embodiments, the power-monitoring module or the system control module
3 may be located on an expansion card, independent from an expansion card, on a
4 motherboard, or on a device connected to an expansion card. The system control module
5 may perform tasks such as shutting off power to devices when functional demand drops
6 below a specified threshold, decreasing the clock speed of selected components when
7 functional demand decreases, increasing the clock speed of selected components when
8 functional demand increases, introducing wait states into logic when functional demand
9 decreases, increasing supplied power when functional demand increases, and decreasing
10 supplied power when functional demand decreases.

11 In another aspect of the invention, a method for regulating power allocated to
12 components within a computer system includes sensing power drawn by a first device within
13 a computer system, the first device having device resources needed to satisfy functional
14 demand required of the first device, monitoring the power drawn and functional demand
15 required of the first device, and regulating power allocated to the first device by optimizing
16 use of the first device resources in accordance with the functional demand of the first device.

17 In another aspect of the invention, a system for regulating power allocated to
18 components within a computer system includes a computer system comprising a processor,
19 main memory, a local bus, and an expansion bus for receiving expansion cards. A first
20 sensor is provided to sense power drawn by a first expansion card operably connected to the
21 expansion bus. A second sensor is provided to sense power drawn by a second expansion
22 card connected to the expansion bus. A system control module is provided to regulate power
23 allocated to the first expansion card and optimize use of resources in accordance with the
24 functional demand of the first expansion card. The system control module is further
25 configured to regulate power allocated to the second expansion card by optimizing use of the
26 device resources in accordance with the functional demand of the second expansion card.
27

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features of the present invention will become more fully apparent from the following description, taken in conjunction with the accompanying drawings. Understanding that these drawings depict only typical embodiments in accordance with the invention and are, therefore, not to be considered limiting of its scope, the invention will be described with additional specificity and detail through use of the accompanying drawings in which:

Figure 1 is a high-level schematic block diagram illustrating one embodiment of selected components within a computer system, including expansion slots provided to accommodate expansion cards or add-on devices;

Figure 2 is a schematic block diagram illustrating one embodiment of an expansion card including a power-monitoring module configured to monitor power consumption and functional demand of the expansion card;

Figure 3 is a schematic block diagram illustrating one embodiment of a system control module used to regulate power allocated to multiple expansion cards within a computer system;

Figure 4 is a schematic block diagram illustrating selected embodiments of functional modules providing functionality to the system control module;

Figure 5 is a flow chart illustrating one embodiment of a process used to adjust and allocate power to various components and expansion cards connected to a bus; and

Figure 6 is a schematic block diagram illustrating one embodiment of a system control module used to allocate and control power to various expansion cards and other permanent devices connected in a computer system.

DETAILED DESCRIPTION OF THE INVENTION

It will be readily understood that the components of the present invention, as generally described and illustrated in the Figures herein, could be arranged and designed in a wide variety of different configurations. Thus, the following more detailed description of the embodiments of systems and methods in accordance with the present invention, as represented in Figures 1 through 6, is not intended to limit the scope of the invention, as claimed, but is merely representative of certain examples of presently contemplated embodiments in accordance with the invention. The presently described embodiments will be best understood by reference to the drawings, wherein like parts are designated by like numerals throughout.

Many of the functional units described in this specification have been labeled as modules, in order to more particularly emphasize their implementation independence. For example, modules may be implemented in software for execution by various types of processors. An identified module of executable code may, for instance, comprise one or more physical or logical blocks of computer instructions that may, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified module need not be physically located together, but may comprise disparate instructions stored in different locations which, when joined logically together, comprise the module and achieve the stated purpose for the module. For example, a module of executable code could be a single instruction, or many instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices.

Modules may also be implemented in hardware as electronic circuits comprising custom VLSI circuitry, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A module may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices or the like.

1 Similarly, operational data may be identified and illustrated herein within modules,
2 and may be embodied in any suitable form and organized within any suitable type of data
3 structure. The operational data may be collected as a single data set, or may be distributed
4 over different locations including over different storage devices, and may exist, at least
5 partially, merely as electronic signals on a system or network.

6 Referring to Figure 1, a computer system 10, such as a personal computer 10, a
7 workstation 10, a server 10, or other computer 10 may include various components providing
8 various functionalities thereto. For example, a computer system 10 may include a central
9 processing unit 12 to process executable and operational data stored in a connected memory
10 device such as random access memory 16, or a hard drive connected to an IDE port 32. The
11 CPU 12 may be connected to a main or local bus 14 having a relatively large bandwidth to
12 accommodate the speed of the CPU 12. The local bus 14 may be connected to various high-
13 speed memory devices 16, 18 where instructions and operational data may be stored for
14 ready and immediate access by the CPU 12.

15 A controller 20 may act as an interface between the CPU 12 and the memory 16, 18.
16 For example, local memory may include an L2 cache 18 and random access memory 16. The
17 L2 cache 18 may be used to speed up data transfers between the CPU 12 and random access
18 memory 16. The L2 cache 18 may also serve as a staging area to speed up instruction
19 execution and data retrieval.

20 The local bus 14 may connect to a bridge 22 acting as an interface between the local
21 bus 14 and other buses, such as a PCI bus 24. The bridge 22 may function as an arbitrator or
22 “traffic cop” for data exchanges between the buses 14, 24, and may resolve differences in
23 protocols, clock speeds, and the like between the buses 14, 24.

24 A bus, such as a PCI bus 24, may be used to interconnect, switch, or multiplex data
25 exchanged between various onboard devices 28, 30, 32, 34, as well as add-on or expansion
26 cards installed into one or several expansion slots 26a-c. For example, a secondary bus 24,
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1 such as a PCI bus 24, may support sound hardware 28, video hardware 30, IDE ports 32 for
2 interfacing with hard drives or other storage devices, or any other number of components 34.

3 In a similar manner, a secondary bus 24, such as a PCI bus 24, may connect to one or
4 more other bridges 36 for interfacing with other buses 38, 42, or components. The bridge 36
5 may interface with other slower legacy buses having lower bandwidths. A legacy bus 38, 42
6 may serve to interface with older, but still useful, expansion cards, or other components 44,
7 46, 48. For example, a bridge 36 may connect to an ISA bus 38 (Industry Standard
8 Architecture) that accepts many slower legacy expansion cards 40a-c. The bridge 36 may
9 also connect via a bus 42 to devices such as a real-time clock 46 that may store the current
10 time and date even when the computer system 10 is powered off.

11 Other devices in the computer system 10 may include non-volatile memory 48 storing
12 a basic input output system 48 (BIOS) to provide an interface between an installed operating
13 system and hardware in the computer system 10. Other devices may include a keyboard and
14 mouse controller 44, or other controllers 44, providing basic input and output functionality to
15 external device such as mice, keyboards, and the like.

16 Referring again to the secondary bus 24, the secondary bus 24 may be rated to supply
17 a specified amount of power to each of the devices 26a-c, 28, 30, 32, 34. Nevertheless, as
18 selected components such as expansion cards include greater performance, these components
19 may draw more power than the bus 24 is rated to supply. Thus, situations may frequently
20 occur in which the bus 24 is overloaded beyond its power rating.

21 Moreover, in certain instances, expansion cards inserted into expansion slots 26a-c, as
22 well as other devices 28, 30, 32, 34, may draw more power than the functional demand on
23 the devices requires at any given time. That is, a component connected to the bus 24 may
24 draw a certain level of power regardless of the load or demand imposed on the device.

25 For example, a network card installed into an expansion slot 26 may only
26 intermittently be operating at its full functional capability, such as when data or files are
27 accessed over a network, or a user is accessing the Internet or other network services by way

1 of the network card. Nevertheless, when the network card is not being used, the network
2 card may continue to draw power, even though in a rest state. This may be due to clock
3 speeds that continue to operate at high speeds needlessly, or because of leakage currents that
4 occur within circuitry or components of the network card, even when at rest. Thus, it would
5 be an improvement in the art to regulate, shut off, increase, or decrease power supplied to an
6 expansion card or other device as power is required by functional demand on the device. It
7 would be a further advance to actually adjust device parameters such as clock speeds, logic
8 wait states, and the like, to reduce power drawn by a selected device.

9 Referring to Figure 2, in selected embodiments, supplemental hardware 59, such as a
10 power-monitoring module 62, is located on an expansion card 50 or other device 50
11 connected to a bus 24, to monitor power drawn by the device 50. One or several sensors
12 64a-c may be used to monitor power used by the device 50 supplied by one or several power
13 supplies 60a-b. The power-monitoring module 62 may monitor and relay the power drawn
14 by the device 50 to a central system control module by way of a signal 76. The sensors 64a-c
15 may sense the current, the voltage, or the like, drawn by the device 50.

16 In selected embodiments, the power-monitoring module 62 also preferably monitors
17 the functional demand 68 required of selected functional components 52 of the expansion
18 card 50 or device 50. For example, functional components 52 of the device 50 may include
19 one or several processors 54, memory devices 56, or other components 58. The power-
20 monitoring module 62 may also monitor various characteristics of the expansion card's
21 functions 52, such as temperature 70, or the like. In selected embodiments, the power control
22 module 62 may output a control signal 72 to the functional components 52 of the expansion
23 card 50 to control or change device parameters of the processor 54, memory 56, or other
24 components 58. In other embodiments, a control signal 74 may be received from a central
25 system control module directly to the functional components 52 of the device to modify
26 clock speed and the like.
27

1 Referring to Figure 3, a system control module 82 is preferably used to monitor a
2 plurality of expansion cards 50a-e and output control signals 74a-e to control functions of
3 each card 50a-e. For example, in one embodiment, a power-monitoring module 62 may be
4 provided for each expansion card 50 or device 50 to gather information with respect to the
5 power consumed, and characteristics of the functional components 52 of each card 50a-e.

6 In selected embodiments, the system control module 82 may be embodied as one or
7 more pieces of hardware located on a motherboard, or other device. The functionality of the
8 system control module 82 may also be provided by a combination of hardware and software,
9 and may be executed by a CPU 12 of the computer system 10. Likewise, as illustrated, one
10 or several power-monitoring modules 62 may be located directly on each expansion card 50
11 or, in other embodiments, may be located at a location off the card 50. Likewise, the current
12 or voltage sensors 64a-c may be located directly on the card 50 or, in other embodiments,
13 may be located off the card 50 such as on a motherboard, to monitor power drawn by one or
14 several expansion cards 50a-e.

15 As illustrated, the system control module 82 is used to monitor and control one or
16 several expansion cards 50a-e located on a secondary bus 24, such as a PCI bus 24.
17 However, the system control module 82 may also be used to monitor and control power used
18 by other devices 28, 30, 32, 34 permanently connected to the bus 24. In addition, apparatus
19 and methods in accordance with the invention need not be limited to buses 24, such as PCI
20 buses 24, but may be used with any bus or grouping of components for which power control
21 is desired. For example, apparatus and methods in accordance with the invention may be
22 used to monitor and control power used by components in a next generation point-to-point
23 switching system.

24 As illustrated in Figure 3, the system control module 82 preferably receives input
25 signals 76a-e with respect to the power consumed and the functional demand of each of the
26 expansion cards 50a-e. The system control module 82 may also provide one or several
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1 control signals 74a-e to control, modify, or optimize selected functional components 52 of the
2 devices 50.

3 Referring to Figure 4, a system control module 82 in one embodiment includes a
4 monitoring module 84 to monitor device parameters or characteristics of various expansion
5 cards 50 or devices 50 in a computer system 10, a calculation module 88 to perform various
6 calculations with respect to the power consumption and control of the expansion cards 50, a
7 control module 90 to control various device parameters or characteristics of the expansion
8 cards 50 or other devices 50, and a support module 92 providing functionality to the system
9 control module 82. In reality, any of the functions described with respect to the modules 84,
10 88, 90, 92 may be located within the system control module 82 or the power-monitoring
11 module 62, either being within the scope of the invention. Thus, the functionality, rather
12 than the location of the modules 84, 88, 90, 92, is intended to be captured by this description.

13 For example, a monitoring module 84 may monitor both the functional demand 94
14 required of a device 50, and the power consumed 96 by the device 50. By “functional
15 demand,” it is meant the functional load or processing required by a particular device 50. In
16 selected embodiments, functional demand 94 may be measured by the number, frequency,
17 peak values, and the like, of operations 110 that are performed by a processor 54 or other
18 component 58 of an expansion card 50 or device 50. Functional demand 94 may also be
19 measured by monitoring data rates 112 transmitted to or from the expansion card 50 or other
20 device 50.

21 In other embodiments, a cache hit ratio 114 may be used to measure the functional
22 demand 94. A cache hit ratio 114 refers to the ratio between the number of occurrences that
23 data is found in a component’s data cache compared to the total number of attempts to access
24 data in the data cache. Likewise, other benchmarks or measurements may be used to
25 measure the functional demand 94 for a selected device 50.

26 The monitoring module 84 may also monitor the power consumed by a device 50 or
27 expansion card 50. The power consumed 96 may be determined by measuring current 116

1 drawn by the device 50, or by measuring fluctuations in voltage 118 due to power drawn.
2 The monitoring module 84 may also measure leakage currents 120 of selected devices 50.
3 Leakage currents 120 may be measured by observing the current or power drawn by a device
4 50 when the functional demand 94 is zero or substantially zero. In situations such as these, it
5 may be desirable to completely shut off a device 50, or shut down selected components 54,
6 56, 58 within a device 50, in order to save power.

7 In other embodiments, the monitoring module 84 may measure the temperature 98 of
8 a device 50 to calculate the amount of power being consumed by a particular device 50. The
9 temperature may then be compared to suitable operating values to determine if it is in range.
10 If it is out of range, the power allocated to one or more of the devices may be reduced. Thus,
11 temperature monitoring may be used in throttling back selected devices with lower functional
12 demands to reduce the temperature in the entire system.

13 In certain embodiments, counters 100 may be used to determine the functional
14 demand 94 imposed on a particular device 50, or power consumed 96 by a device 50. For
15 example, a counter 100 may be used to count the number of operations 110 performed by a
16 selected device 50, quantities or speeds of data processed by a device 50, numbers of hits 114
17 to a device's cache compared to the number of times data was actually found in the cache,
18 and the like.

19 In selected embodiments, the system control module 82 includes a calculation module
20 88 configured to perform various calculations with respect to the optimization of power
21 allocated to various devices 122. For example, a calculation module 88 may determine the
22 number of devices 50 that are sharing a finite quantity of power. As expansion cards 50 or
23 other devices 50 are added or removed from a computer system 10, the calculation module
24 88 may determine the impact or affect this may have on the overall power consumption of
25 the devices 50. In certain embodiments, a calculation module 88 may reallocate power
26 resources as the number of devices 122 changes.
27

1 The calculation module 88 in selected embodiments also determines the amount of
2 power that is allocated 124 to each device 50. Thus, if a device 50 exceeds the allocated
3 power 124, measures may be taken to correct this condition or to compensate by allocating
4 additional power. In selected embodiments, the calculation module 88 may calculate the
5 maximum or total power 126 that is available. That is, if the functional demand 94 on a
6 selected device 50 increases such that it requires additional power, the calculation module 88
7 may allocate additional power based on the power available 126. If the maximum power
8 available 126 has been allocated, the calculation module 88 may prevent a selected device 50
9 from drawing additional power. Instead, power from another device 50 may be allocated to
10 the selected device 50.

11 In other embodiments, the calculation module 88 may calculate the total power
12 consumed 128 by individual devices 50, several devices 50, or all devices 50 drawing power
13 on a selected bus 24. The calculation module 88 may also calculate a safety factor 130. A
14 safety factor 130 may be a level of power allocated to a particular device 50 in excess of what
15 is actually required by the functional demand 94 on the device 50. Thus, in situations where
16 a surge or rapid fluctuation of power is needed to satisfy an increase in functional demand
17 94, a safety factor 130 may ensure that power is available.

18 In selected embodiments, the system control module 82 may include a control module
19 90. The control module 90 may have the primary task of controlling, adjusting, and
20 optimizing device parameters of various components such as a processor 54, a memory
21 device 56, or other component 58 providing functions 52 to an expansion card 50 or device
22 50. For example, a control module 90 may direct a selected action 102 toward a parameter
23 104.

24 Actions 102 may include shutting down 132 a device 50 or components 54, 56, 58 of
25 a device 50, throttling up 134 selected device parameters 104, or throttling down 136
26 selected device parameters 104. For example, the control module 90 may shut down 132,
27 throttle up 134, throttle down 136, or the like, a processor clock 138 driving a processor 54,

1 introduce wait states 140 in logic, or adjust other components 142 such as bus speeds, as
2 needed. Those parameters 104 illustrated simply represent certain examples of device
3 parameters that may be modified or adjusted and are not an exhaustive list of all device
4 parameters that may adjust the power consumed by a selected expansion card 50 or other
5 device 50.

6 A system control module 82 may receive support 92 from a variety of sources. For
7 example, support 92 may be provided by software 106 and hardware 108 to provide
8 necessary functionality to the system control module 82. For example, in selected
9 embodiments, any or all of the modules within the system control module 82 may be
10 implemented by kernel extensions 144 to an operating system run on a computer system 10,
11 drivers 146 driving selected hardware, or embedded operating systems 148 loaded onto
12 microcontrollers, field programmable gate arrays, and the like.

13 Hardware 108 used to implement the system control module 82 may be on-board 150,
14 meaning it is located on any of the expansion cards 50 or devices 50, and/or off-board 152,
15 meaning it is located on other devices such as a computer system motherboard. The
16 hardware may be implemented as piggyback 154 hardware attached or plugged into a device
17 50 or expansion card 50. Indeed, any number of solutions using hardware 108, software 106,
18 or a combination thereof, may be used to implement an apparatus and method in accordance
19 with invention, the primary concept being the control and conservation of power allocated to
20 one or several devices 50 in a computer system 10.

21 Referring to Figure 5, in selected embodiments, a process 156 in accordance with the
22 present invention includes determining 160 or calculating 160 the functional demand of a
23 selected device 50. For example, calculating 160 functional demand may include measuring
24 the number, frequency, or speed of operations 162 performed by a selected device 50, or
25 measuring the quantity or speed of data transferred 164 to or from a device 50 or expansion
26 card 50. A process 156 may further include calculating 166 device parameters 104 needed to
27 satisfy the calculated functional demand.

1 As mentioned above, device parameters 104 may include parameters such as clock
2 speed, bus speed, logic wait states, and the like, that may be adjusted to reduce the power
3 consumed by a device 50. Once required device parameters 104 have been calculated, a
4 process 156 may adjust 168 the device parameters to the calculated values. This may include
5 increasing or reducing clock speeds, bus speeds, introducing wait states into logic, and the
6 like, to agree with the calculated values.

7 Once the device parameters have been adjusted 168, the process 156 continues and
8 determines 170 whether an increase in the functional demand of one or more devices 50 has
9 occurred. For example, if it is determined that the functional demand of one of the devices
10 50 has increased, a process 156 may throttle up 178 the device to accommodate the increase
11 in functional demand. Throttling up one device may require throttling down another device
12 which has a reduced demand. Once the device parameters have been adjusted 178, the
13 process 156 may return to the determination 170.

14 If, the functional demand has not increased, the process 156 continues on to
15 determine 172 if functional demand has on one or more of the devices has decreased. If
16 functional demand has decreased, the process 156 may throttle down 176 one or more of the
17 devices 50 and return to the determination 170. If, however, functional demand has not
18 decreased, the process 156 may continue directly to determination 170. Thus, if neither an
19 increase nor a decrease in functional demand has occurred, the process 156 may simply cycle
20 between determination 170 and determination 172 until an increase or decrease occurs.

21 Consequently, the level of demand or power drawn by one device may affect the
22 adjustment of power drawn by the other devices. If one device experiences a high demand or
23 a high level of power usage, power levels or other operating parameters in others of the
24 devices experiencing a lesser demand may be decreased. In one embodiment, the total power
25 drawn is kept under a selected level, while adjusting the various devices according to the
26 functional demand on the devices.
27

1 Multiple dependent thresholds may be provided between the devices to allocate
2 power between the devices according to various selected criteria. Parameters such as current
3 power usage, anticipated power usage, functional demand, and temperature may be examined
4 for each card to determine the criteria. These parameters are compared against
5 predetermined threshold levels to allocate power between the multiple devices. Thus, the
6 devices may be collectively adjusted according to multiple dependent thresholds.

7 The monitoring of the devices may also be used to isolate a failure or pending failure
8 to a device in the system. By comparing a vector of the current power, temperature, and
9 functional demand to a set of stored vector ranges, a failure can be predicted or isolated to a
10 device when the values fall outside a predetermined range. For example, when temperature
11 on a card is higher than expected for the demand and power values reported, a failure or
12 pending failure may be indicated and power to the device terminated.

13 Referring to Figure 6, in one contemplated embodiment given by way of example, a
14 system control module 82 is used to monitor and control functional parameters and power
15 consumed by one or several expansion cards 50a-c, and devices such as sound hardware 28,
16 video hardware 30, IDE ports 32 used to access devices such as hard drives, or other devices
17 34 that may be connected to a bus 24 like a PCI bus 24.

18 The system control module 82 may be implemented exclusively by hardware located
19 in the computer system 10, or may be implemented by a combination of hardware and
20 software loaded onto the computer system 10. Those skilled in the art will recognize that an
21 apparatus and method in accordance with the invention need not be limited to buses 24, such
22 as PCI buses 24, ISA buses 38, or other buses available currently or in the future, but may be
23 used in any system comprising multiple devices 50 or components 50 sharing power from a
24 single power supply or power source.

25 Thus, the system control module 82 may be used to conserve and allocate power in a
26 wide variety of computer systems 10. The examples illustrated have primarily been
27 descriptive of selected personal computers 10, workstations 10, and the like. However, an

1 apparatus and method in accordance with the invention may be used in higher-end computers
2 such as servers, mainframe computers, and the like, all within the scope of the present
3 invention.

4 The present invention may be embodied in other specific forms without departing
5 from its essence or essential characteristics. The described embodiments are to be
6 considered in all respects only as illustrative, and not restrictive. The scope of the invention
7 is, therefore, indicated by the appended claims, rather than by the foregoing description. All
8 changes within the meaning and range of equivalency of the claims are to be embraced
9 within their scope.

10 What is claimed is:
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